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14. ABSTRACT
We address the target recognition problem by focusing on intermediate-level vision. Early biological vision extracts edges and contours of various lengths. High-level recognition is either view or template-based, which is fragile with respect to lighting, size, or clutter; or medial-axis-based, which requires a perfect bounding contour. Diffusion processes are central to neurobiology, and we have discovered how to use them to bridge the gap between (local) edges and

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Report Title

Neurobiologically Inspired Geometric Diffusion for Target Recognition

ABSTRACT

We address the target recognition problem by focusing on intermediate-level vision. Early biological vision extracts edges and contours of various lengths. High-level recognition is either view or template-based, which is fragile with respect to lighting, size, or clutter; or medial-axis-based, which requires a perfect bounding contour. Diffusion processes are central to neurobiology, and we have discovered how to use them to bridge the gap between (local) edges and (global) descriptions for matching. We have proved that the equilibria of these distributions signals information from the distance map that underlies medial axis computations. This equilibrium distribution therefore makes explicit global pattern from local features and can be used for matching. We have shown how this provides a novel solution to detecting airports and other "complex features" in imagery, and how it suggests a novel solution to the border-ownership problem in neuroscience.

Enter List of papers submitted or published that acknowledge ARO support from the start of the project to the date of this printing. List the papers, including journal references, in the following categories:

(a) Papers published in peer-reviewed journals (N/A for none)

Received Paper

TOTAL:

Number of Papers published in peer-reviewed journals:

(b) Papers published in non-peer-reviewed journals (N/A for none)

Received Paper

TOTAL:

Number of Papers published in non peer-reviewed journals:

(c) Presentations

1. NGA NARP Symposium, Washington, DC, 29 Sept. - 1 Oct, 2009.
2. Neuromorphic Cognitive Engineering Workshop, Telluride, CO, 25 - 29 June, 2009
3.Pattern formation in plants, 1: uniform production and proportional destruction of auxin, Plant Vascular Development, Banff, Alberta, 8 - 10 May, 2009.
4. Pattern formation in plants, 2: facilitated transport, constant gradient hypothesis, and long-distance communication, Plant Vascular Development, Banff, Alberta, 8 - 10 May, 2009.

Number of Presentations: 4.00

Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Received Paper

TOTAL:

Number of Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Peer-Reviewed Conference Proceeding publications (other than abstracts):

Received Paper

TOTAL:

Number of Peer-Reviewed Conference Proceeding publications (other than abstracts):

(d) Manuscripts

Received		Paper
2012/03/10 0!	6	Steven W. Zucker. Distance Images and the Enclosure Field:Applications in Intermediate-Level Computerand Biological Vision, Dagstuhl Proceedings (03 2012)
2012/03/10 0!	5	Steven W. Zucker. Local Field Potentials and Border Ownership:a conjecture about computation in visual cortex, J Physiol (Paris) (11 2011)
2011/10/27 1!	4	Pavel Dimitrov, Matthew Lawlor, Steven W. Zucker. Distance Images and Intermediate-Level Vision, SSVM 2011, LNCS667 (10 2011)
2011/10/27 1!	3	Pavel Dimitrov, Steven W. Zucker. Distance Maps and Plant Development #2, arXiv.org (05 2009)
2011/10/27 1!	2	Pavel Dimitrov, Steven W. Zucker. Distance Maps and Plant Development #1, arXiv.org (05 2009)

TOTAL: 5

Number of Manuscripts:

Books

Received Paper

TOTAL:

Patents Submitted

Patents Awarded

Awards

Advisory Board, Center for Stochastic Geometry and Bioimaging, Copenhagen.
Ian Howard Lecture in Vision Science}, Toronto, 9 April 2010.
Adrian Seminar in Neuroscience, University of Cambridge, 12 October, 2009.
Keynote Address, Johansen Workshop, University of Copenhagen, 24 - 25 January, 2008.
Plenary Speaker,Geometric Analysis and Its Applications, Bern, Switzerland, 21 - 24 January, 2008.

Graduate Students

NAME	PERCENT_SUPPORTED	Discipline
Pavel Dimitrov	0.25	
Justin Hart	0.19	
Matthew Lawlor	0.10	
Daniel Holtmann-Rice	0.38	
FTE Equivalent:	**0.92**	
Total Number:	**4**	

Names of Post Doctorates

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Names of Faculty Supported

NAME	PERCENT_SUPPORTED	National Academy Member
Steven W. Zucker	0.08	
FTE Equivalent:	**0.08**	
Total Number:	**1**	

Names of Under Graduate students supported

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Student Metrics

This section only applies to graduating undergraduates supported by this agreement in this reporting period

The number of undergraduates funded by this agreement who graduated during this period: 0.00

The number of undergraduates funded by this agreement who graduated during this period with a degree in science, mathematics, engineering, or technology fields:...... 0.00

The number of undergraduates funded by your agreement who graduated during this period and will continue to pursue a graduate or Ph.D. degree in science, mathematics, engineering, or technology fields:...... 0.00

Number of graduating undergraduates who achieved a 3.5 GPA to 4.0 (4.0 max scale):...... 0.00

Number of graduating undergraduates funded by a DoD funded Center of Excellence grant for Education, Research and Engineering:...... 0.00

The number of undergraduates funded by your agreement who graduated during this period and intend to work for the Department of Defense 0.00

The number of undergraduates funded by your agreement who graduated during this period and will receive scholarships or fellowships for further studies in science, mathematics, engineering or technology fields:...... 0.00

Names of Personnel receiving masters degrees

NAME
Total Number:

Names of personnel receiving PHDs

NAME	
Pavel Dimitrov	
Total Number:	**1**

Names of other research staff

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Sub Contractors (DD882)

Inventions (DD882)

Scientific Progress

Background

There are a range of target recognition problems, starting with extremely simple ones such as bar code recognition and extending through more difficult problems such as face detection and recognition. Finally, there are those problems of interest to the military, security, medical and surveillance communities that are less well defined. They involve notions of detecting a ``threat'' or a change in an ``airport'' but without proper computational definitions of them.

Approaches to all of these problems begin with the idea that local features can be aggregated into a kind of hierarchy, with smaller, more local features giving rise to slightly less local ones, and so on until a classifier stage is reached. Significant steps along these lines include Low [1], Viola [2] and LeCunn [3].

Poggio and colleagues [4] have applied a similar methodology to object recognition, but with a biological motivation. Building on the idea that the visual parts of the brain consist of a ``hierarchy'' of different areas, and assuming that each area builds a description that is more abstract and global than the previous one, a staged linear combination is combined with the MAX operation to emulate the feedforward pathways for object recognition. However this system is effectively the same in its capability to those above.

Problem Statement

We address the target recognition problem by focusing on intermediate-level vision. Early biological vision extracts edges and contours of various lengths, but these essentially describe local information. High-level recognition is either template-based, which is fragile with respect to lighting, size, or clutter; or medial-axis-based, which requires a perfect bounding contour. Intermediate-level vision must bridge this gap.

The heart of our approach can be described in two ways. First, mathematically, we have discovered a theorem about how aspects of the distance map, a central component to shape descriptions, can be ``read out'' of the equilibrium of a diffusion process deriving from edge arrangements. From a neurobiological perspective, it incorporates feedforward and feedback projections, both of which are fundamental, and does so in a novel fashion.

More generally, diffusion processes are central to neurobiology, and we have discovered how to use them to bridge the gap between (local) edges and (global) descriptions for matching. Suppose edges could produce an abstract ``substance'' which diffuses through surrounding substrate until equilibrium. We have proved that the equilibria of these distributions approximate the distance map that underlies medial axis computations. This equilibrium distribution therefore makes explicit global pattern from local features and can be used for matching. Our goal is to exploit this for recognition by defining features on this new map. If successful, new, improved and extremely efficent ATR algorithms should arise from these biologically-based techniques.

Summary of the Most Important Results

1. Development of a system of reaction-diffusion differential equations to show how area effects can be integrated into ``action at a distance'' phenomena.

2. Applied this system to a problem in biology: what is the signal that ground cells send to vein cells to initiate new vein formation?

3. Applied this system to a problem in computer vision: detection of airports from high-altitude imagery. To our knowledge this system is the first to formulate a formal approach to such ``complex feature detection'' problems.

Bibliography

1. Lowe, David G. 'Distinctive Image Features from Scale Invariant Features', International Journal of Computer Vision, Vol. 60, No. 2, 2004, pp. 91-110

2. Paul Viola and Michael Jones,
Robust Real-Time Face Detection
International Journal of Computer Vision 57(2), 137<E2><80><93>154, 2004

3.Yann LeCun, Fu-Jie Huang and Leon Bottou: Learning Methods for Generic Object Recognition with Invariance to Pose and Lighting, Proceedings of CVPR'04, IEEE Press, 2004

4. Serre, T., Wolf, L., Bileschi, S., Riesenhuber, M., & Poggio, T. (2007). Robust Object Recognition with Cortex-like Mechanisms. IEEE Transactions on Pattern Analysis and Machine Intelligence 29(3): 411-426

Appendix

During the year we have extended in detail our a model for diffusion; we have written several papers about it that relate to both biology (predicting the manner in which veins develop in plants) and computer vision (definition of complex features such as airports). Such configurations are difficult to define recognition procedures for because, while airports have runways and buildings, they need not be in precisely the same or even approximate relationships. Thus existing computer vision techniques cannot be applied. We are continuing to develop the analogy with plants and we are exploring the distance-map information and what this implies for complex features. Our major new work in the past year was the extraction of basic information from these ``distance images'' using non-linear dimensionality reduction techniques. The surprising result is that a manifold emerges with the principle eigenfunctions spanning density and edge orientation, somewhat analagously to the (intensity, hue, saturation) representation of color. Current work is defining classifiers for airports on this manifold.

Technology Transfer